

Thirty-Year Trends in Mortality from Cerebrovascular Diseases in Korea

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Background and Objectives: Cerebrovascular disease is a leading cause of mortality and morbidity in Korea. Understanding of cerebrovascular disease mortality trends is important to reduce the health burden from cerebrovascular diseases. We examined the changing pattern of mortality related to cerebrovascular disease in Korea over 30 years from 1983 to 2012.

Subjects and Methods: Numbers of deaths from cerebrovascular disease, hemorrhagic stroke, and cerebral infarction were obtained from the national Cause of Death Statistics. Crude and age-adjusted mortality rates were calculated for men and women for each year. Penalized B-spline methods, which reduce bias and variability in curve fitting, were used to identify the trends of 30-year mortality and identify the year of highest mortality.

Results: During the 30 years, cerebrovascular disease mortality has markedly declined. The age-adjusted cerebrovascular disease mortality rate has decreased by 78% in men and by 68% in women. In the case of hemorrhagic stroke, crude mortality peaked in 2001 but age-adjusted mortality peaked in 1994. Between 1994 and 2012, age-adjusted mortality from hemorrhagic stroke has decreased by 68% in men and 59% in women. In the case of cerebral infarction, crude and age-adjusted mortality rates steeply increased until 2004 and 2003, respectively, and both rates decreased rapidly thereafter.

Conclusion: Cerebrovascular disease mortality rate has significantly decreased over the last 30 years in Korea, but remains a health burden. The prevalence of major cardiovascular risk factors are still highly prevalent in Korea. (Korean Circ J 2016;46(4):507-514)

KEY WORDS: Cerebrovascular disorders; Stroke; Mortality; Trends; Korea.

Introduction

Cerebrovascular disease mortality ranks as the second most common cause of death around the world,¹⁾ but, in Korea, cerebrovascular disease is the leading cause of death among single -organ diseases.²⁾³⁾ Every year approximately 105000 people experience a new or recurrent stroke and more than 26000

people die.²⁾ Fortunately, there have been great improvements in the management of stroke over the last decades. Among the Organization for Economic Cooperation and Development (OECD) member countries, Korea recorded the lowest in-hospital, 30-day case-fatality rate for ischemic stroke and the third lowest rate for hemorrhagic stroke in 2009.²⁾⁴⁾ Understanding cerebrovascular disease mortality trends is important to reduce the health burden. Mortality trends of cerebrovascular diseases have been reported in many countries including Korea.⁵⁻⁷⁾ However, there are only a few studies reporting long-term trends in mortality from cerebrovascular diseases in the Korean population. Thus, we examined the 30-year changing pattern of cerebrovascular disease mortality in Korea to further understand and quantify recent trends in mortality by analyzing the Cause of Death statistics from Statistics Korea.

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Subjects and Methods

Annual mortality data were obtained from the Korean Statistical

Information Service managed by Statistics Korea (former the Korea National Statistical Office). Mortality statistics with cause of death information have been available since 1983. Causes of death were coded according to the International Classification of Disease, 10th Revision. For the purpose of this study, deaths from cerebrovascular disease (I60–69) were further classified into hemorrhagic stroke (I60–62), cerebral infarction (I63), unspecified stroke (I64), and other cerebrovascular diseases (I65–69). Hemorrhagic stroke included subarachnoid hemorrhage (I60), intracerebral hemorrhage (I61), and other nontraumatic intracranial hemorrhage (I62). Mortality rates from total heart diseases (I00–13 and I20–51) and ischemic heart disease (I20–25) were previously reported.⁸⁾

Crude and age-adjusted mortalities were calculated only for cerebrovascular disease, hemorrhagic stroke, and cerebrovascular disease, because reported numbers of deaths from unspecified stroke and other cerebrovascular diseases showed great fluctuation in the 1990s and early 2000s, probably due to changes in classifying causes of death. We calculated age-adjusted mortality through a direct standardization method using the age distribution of the

Korean population in 2000 as the standard population. We analyzed data using 10-year age intervals and the same population structure for standardization in men and women to compare mortality by sex. We also presented penalized B-Splines to explore the non-linear pattern of the crude death rate and age-adjusted death rate per 100000 over time in years. Penalized regression methods are used to quantify the notion of roughness of a curve through a suitable penalty function and the necessary compromise between bias and variability in curve fitting can be explicit in estimation of the problem.⁹⁾

Results

Numbers of deaths from cerebrovascular disease

Table 1 and Fig. 1 show the number of deaths from cerebrovascular diseases for each year. The absolute number of deaths from cerebrovascular disease did not change much between 1983 and 1990, but it increased rapidly in the early 1990s then stayed high

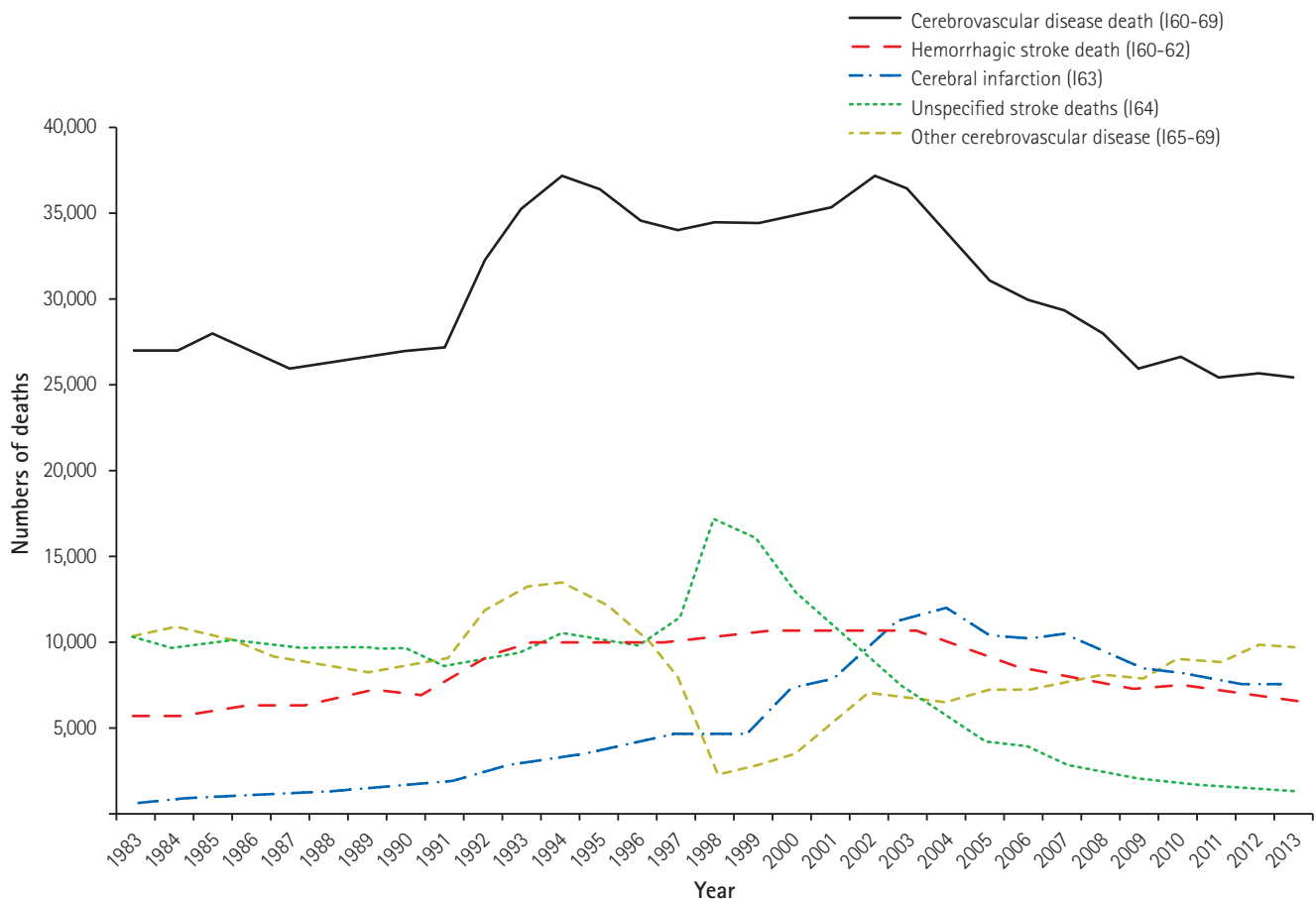


Fig. 1. Number of deaths from cerebrovascular disease.

until 2002. However, after 2002, the number of deaths from cerebrovascular disease has consistently declined. The number of deaths from cerebrovascular disease was 26922 in 1983, peaked at 37131 in 1994, and decreased to 25447 by 2013. Number of deaths from hemorrhagic stroke peaked in 2002, while deaths from cerebral infarction reached its peak in 2004. In 1983, deaths from hemorrhagic stroke (n=5549) were almost 8 times more common than deaths from cerebral infarction (n=703). However, since 2003, cerebral infarction has been the most common cause of death

among cerebrovascular diseases. The number of deaths from unspecified stroke increased steeply between 1996 and 1998, but it rapidly decreased until recently since 1998.

Crude and age-adjusted mortality from cerebrovascular disease

The crude mortality rate from cerebrovascular disease showed fluctuating patterns until 2002, but thereafter it decreased. In the 1980s, the crude mortality rate for men was higher than for women, but the gender difference gradually decreased and has

Table 1. Numbers of deaths from cerebrovascular diseases

Year	Cerebrovascular disease (I60-69)			Hemorrhagic stroke (I60-62)			Cerebral infarction (I63)			Unspecified stroke (I64)			Other cerebrovascular disease (I65-69)		
	Total	Men	Women	Total	Men	Women	Total	Men	Women	Total	Men	Women	Total	Men	Women
1983	26922	14749	12173	5549	3190	2359	703	381	322	10254	5713	4541	10416	5465	4951
1984	26919	14551	12368	5623	3160	2463	758	416	342	9736	5298	4438	10802	5677	5125
1985	27883	15047	12836	6235	3484	2751	1070	579	491	10117	5479	4638	10461	5505	4956
1986	26966	14513	12453	6371	3557	2814	1172	626	546	9941	5347	4594	9482	4983	4499
1987	25984	13693	12291	6230	3371	2859	1181	612	569	9570	5087	4483	9003	4623	4380
1988	26234	13722	12512	6679	3606	3073	1238	614	624	9680	5064	4616	8637	4438	4199
1989	26505	13848	12657	7230	3788	3442	1533	820	713	9574	4947	4627	8168	4293	3875
1990	27039	13902	13137	6909	3590	3319	1681	898	783	9808	5081	4727	8641	4333	4308
1991	27152	13680	13472	7535	3908	3627	1897	1035	862	8739	4298	4441	8981	4439	4542
1992	32236	15642	16594	8969	4486	4483	2495	1297	1198	9125	4458	4667	11647	5401	6246
1993	35216	16943	18273	9802	4817	4985	2803	1433	1370	9450	4607	4843	13161	6086	7075
1994	37131	17793	19338	10022	5001	5021	3149	1644	1505	10502	4995	5507	13458	6153	7305
1995	36416	17300	19116	9868	4822	5046	3767	1915	1852	10337	4988	5349	12444	5575	6869
1996	34590	16508	18082	10052	4906	5146	4111	2090	2021	9788	4661	5127	10639	4851	5788
1997	33966	16467	17499	9946	4917	5029	4449	2299	2150	11565	5553	6012	8006	3698	4308
1998	34464	16555	17909	10197	5045	5152	4451	2275	2176	17201	8037	9164	2615	1198	1417
1999	34374	16390	17984	10653	5200	5453	4944	2498	2446	16151	7426	8725	2626	1266	1360
2000	34754	16537	18217	10695	5240	5455	7357	3496	3861	13324	6224	7100	3378	1577	1801
2001	35295	17035	18260	10766	5270	5496	7987	3839	4148	11219	5409	5810	5323	2517	2806
2002	37067	17511	19556	10839	5318	5521	10027	4686	5341	9126	4212	4914	7075	3295	3780
2003	36396	17176	19220	10751	5265	5486	11479	5257	6222	7202	3311	3891	6964	3343	3621
2004	34003	16166	17837	9874	4837	5037	11793	5430	6363	5768	2669	3099	6568	3230	3338
2005	31195	14886	16309	9098	4405	4693	10664	4988	5676	4226	1990	2236	7207	3503	3704
2006	29951	14460	15491	8526	4150	4376	10177	4767	5410	4005	1960	2045	7243	3583	3660
2007	29277	13941	15336	8030	3965	4065	10693	4904	5789	2944	1391	1553	7610	3681	3929
2008	27932	13553	14379	7733	3877	3856	9582	4444	5138	2568	1283	1285	8049	3949	4100
2009	25836	12648	13188	7207	3586	3621	8475	4010	4465	2113	1047	1066	8041	4005	4036
2010	26514	12865	13649	7503	3717	3786	8164	3791	4373	1908	943	965	8939	4414	4525
2011	25404	12185	13219	7112	3518	3594	7860	3520	4340	1653	828	825	8779	4319	4460
2012	25744	12380	13364	6767	3337	3430	7490	3469	4021	1554	706	848	9933	4868	5065
2013	25447	12096	13351	6710	3318	3392	7558	3468	4090	1387	629	758	9792	4681	5111

reversed since 1991. The crude mortality rate from cerebrovascular disease in 1983 was 73.3 per 100000 in men and 61.5 per 100000 women. In 2012, the crude mortality rate per 100000 was 49.2 for men and 53.1 for women. After the highest crude mortality rate in 1994, there were 33% and 14% mortality decreases in men and women, respectively, until 2012.

Age-adjusted mortality rates from cerebrovascular disease has decreased too, until recently, but the rate has been always higher in men than in women. In 1983, the age-adjusted mortality rate for men was about 2 times higher than for women (124.3 vs. 68.1 per 100000). But the sex difference has gradually reduced to 28.7 per 100000 men and 17.2 per 100000 women in 2012 (Fig. 2).

Crude and age-adjusted mortality from hemorrhagic stroke

Crude mortality rate from hemorrhagic stroke showed upward trends between 1983 and 2001. But, after 2001, the rate has rapidly decreased. The crude mortality rate for men was higher than for

women until 1991, but thereafter the rate for women was higher than men. In 1983, the crude mortality rate from hemorrhagic stroke per 100000 was 15.8 for men and 11.9 for women, but the corresponding rate was 13.3 for men and 13.7 for women in 2012. After the highest mortality rate in 2001, there was about a 39.8% decrease in men and 41.5% decrease in women until 2012.

Age-adjusted hemorrhagic stroke mortality rate peaked in 1994, then the rate decreased in both men and women. Unlike crude mortality, the age-adjusted mortality rate has been consistently higher in men than in women. The age-adjusted hemorrhagic stroke mortality rate per 100000 was 24.4 for men and 14.2 for women in 1983. However, the corresponding rate decreased to 8.6 for men and 5.8 for women by 2012. After the highest age-adjusted mortality rate in 1994, there was a 68.1% decrease in men and a 41.5% decrease in women until 2012 (Fig. 3). It is also notable that crude hemorrhagic stroke mortality peaked in 2001, but the age-adjusted mortality peaked much earlier in 1994.

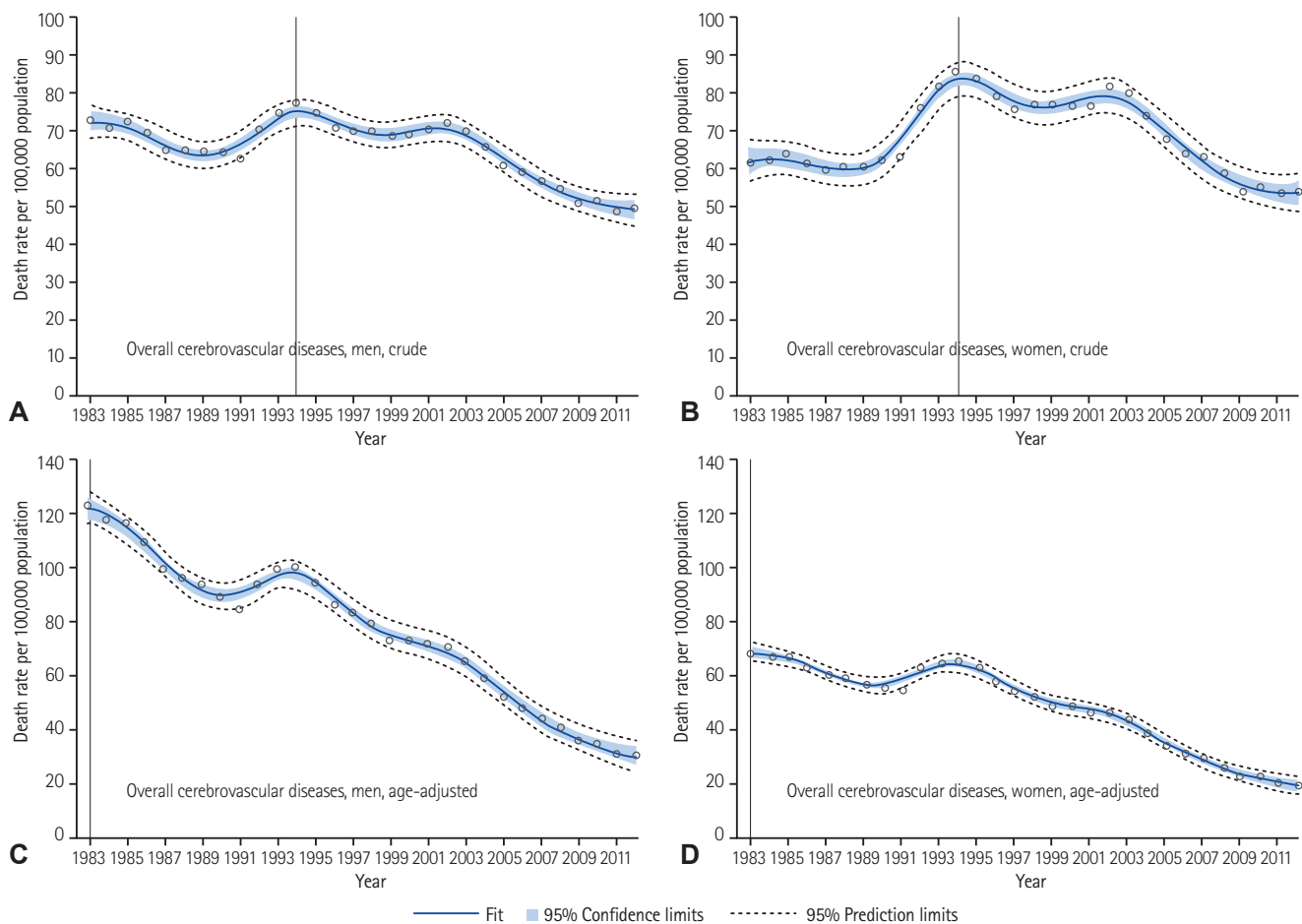


Fig. 2. Crude and age-adjusted mortality from cerebrovascular diseases fitted by Penalized B-Splines method. (A) Crude mortality from cerebrovascular diseases in men. (B) Crude mortality from cerebrovascular diseases in women. (C) Age-adjusted mortality from cerebrovascular diseases in men. (D) Age-adjusted mortality from cerebrovascular diseases in women.

Crude and age-adjusted mortality rates from cerebral infarction

Crude mortality rate from cerebral infarction increased until 2004. But, thereafter, the rate has rapidly decreased. Crude mortality rate per 100000 was 1.9 for men and 1.6 for women in 1983, which increased to 22.3 in men and 26.3 for women in 2004, then decreased to 13.8 for men and 16 for women by 2012. After the highest age-adjusted mortality rate in 2004, there was a 30.7% decrease in men and 32.2% decrease in women.

Age-adjusted cerebral infarction mortality rates peaked in 2003. Unlike crude mortality, the age-adjusted cerebral infarction mortality rate has been consistently higher in men than in women. After the highest age-adjusted mortality in 2003, there was about 61.8% decrease in men and 65.6% decrease in women (Fig. 4). Figures without penalized regression splines for cerebrovascular diseases are provided as supplemental data (Supplementary Figs. 1 to 3 in the online-only Data Supplement).

Discussion

Our study reports the death rate of major cerebrovascular diseases in the Korean population and their trends over the last 30 years. The age-standardized mortality rate from cerebrovascular diseases has significantly decreased since 1983 in Korea and the decline in mortality from cerebrovascular diseases was more prominent in men than women. Over the last three decades, the age-adjusted mortality rate from cerebrovascular diseases decreased, but temporarily increased between 1991 and 1993. This fluctuation might be due to changes of classification of the Cause of Death Statistics in Korea. During the same time period, deaths from hypertensive disease (I10-I15) significantly decreased.⁸⁾

In most developed countries, cerebrovascular disease had been among the leading causes of death in the past, but it has decreased in recent decades.¹⁰⁾¹¹⁾ In particular, Australia, New Zealand, and the UK showed a continuous decline in cerebrovascular disease

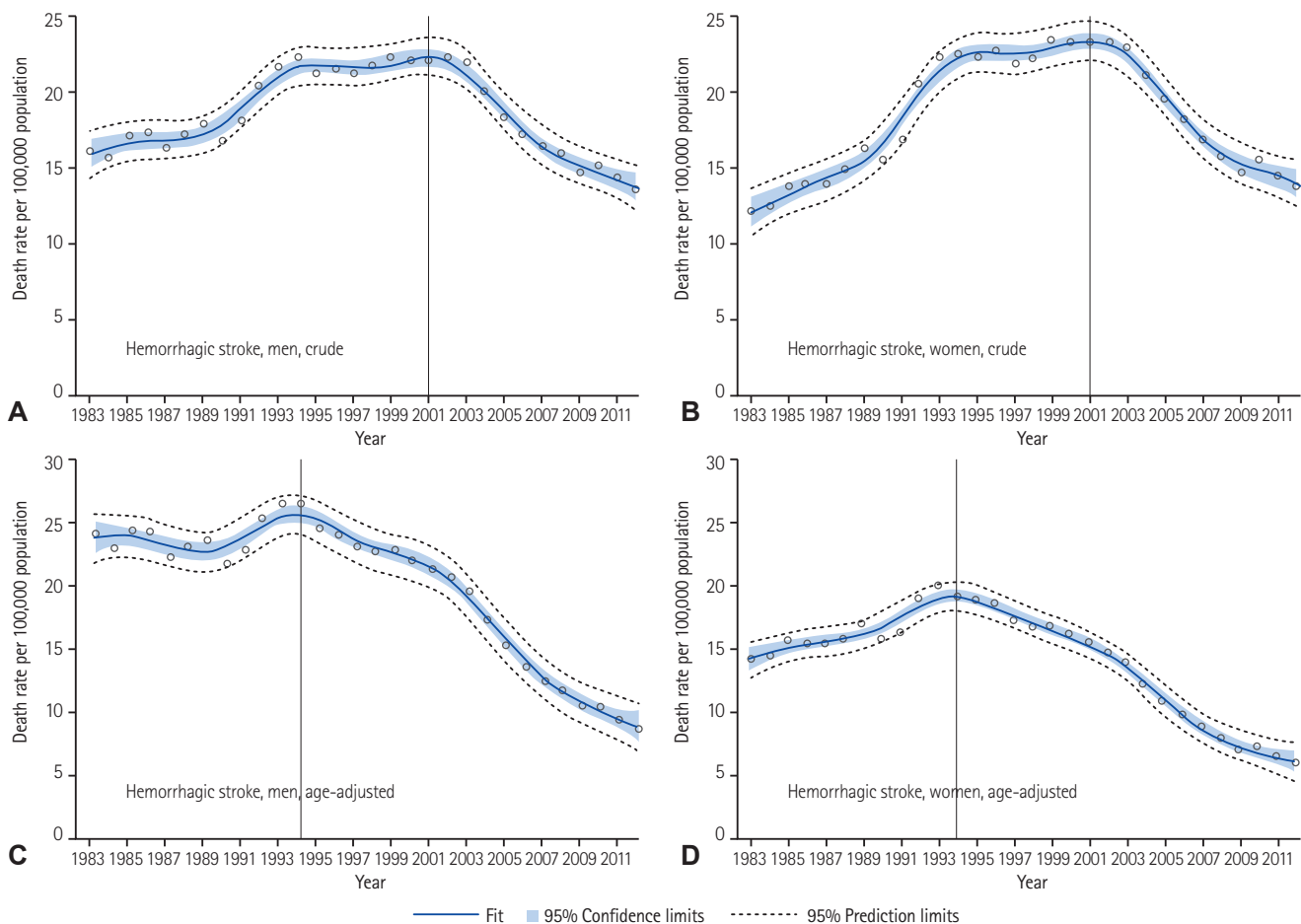


Fig. 3. Crude and age-adjusted mortality from hemorrhagic stroke fitted by Penalized B-Splines method. (A) Crude mortality from hemorrhagic stroke in men. (B) Crude mortality from hemorrhagic stroke in women. (C) Age-adjusted mortality from hemorrhagic stroke in men. (D) Age-adjusted mortality from hemorrhagic stroke in women.

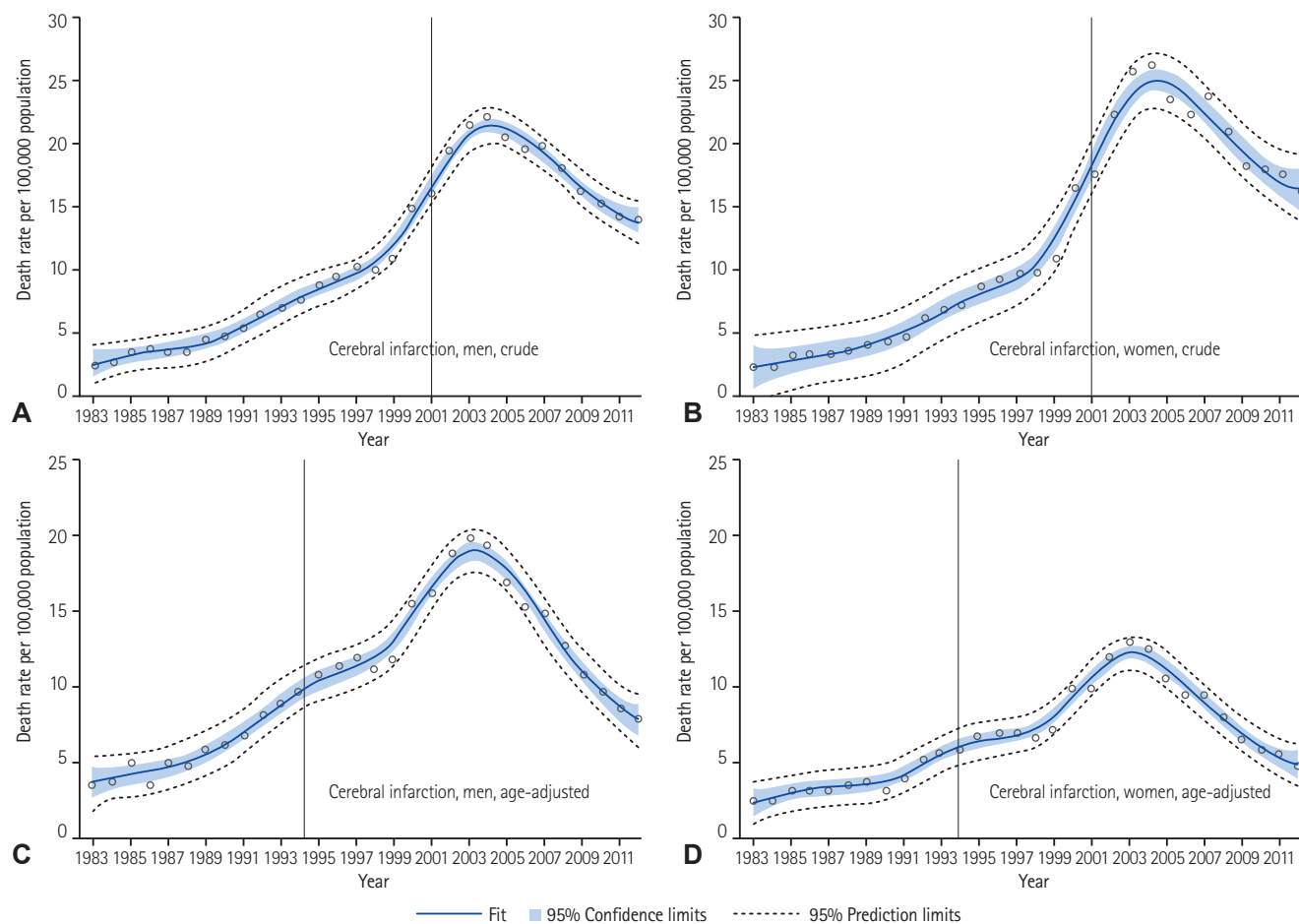


Fig. 4. Crude and age-adjusted mortality from cerebral infarction fitted by Penalized B-Splines method. (A) Crude mortality from cerebral infarction in men. (B) Crude mortality from cerebral infarction in women. (C) Age-adjusted mortality from cerebral infarction in men. (D) Age-adjusted mortality from cerebral infarction in women.

mortality since 1950. The United States showed a steep declining trend since the 1970s and the trend was more prominent in men than women.¹⁰⁻¹²⁾ Among Asian countries, Japan had the highest cerebrovascular disease mortality in the 1950s (433 per 100,000 in men in 1957), but the rate significantly decreased to less than 100 per 100,000 by 2004.⁶⁾¹⁰⁾ Recent studies reported that the stroke mortality rate of Korea was double that of Japan in the beginning of the 2000s,¹⁰⁾ although both Japan and Korea showed decreasing mortality trends for stroke at that time.¹³⁾

A number of studies reported the accelerated decline in stroke mortality during the late 1970s and the early 1980s. Among them, some earlier studies reported declining trends in the stroke incidence rate as well as stroke fatalities during the 1970s,¹⁴⁾¹⁵⁾ suggesting that the effect of stroke incidence rate on stroke mortality.¹⁴⁾ However, there was no significant association between stroke mortality and stroke incidence in Sweden.¹⁵⁾ This study reported that a decline of mortality from stroke may be due to a decline of smoking and

blood pressure (BP) together with an increase in the use of anti-hypertensive treatments rather than changes of stroke incidence.¹⁵⁾ Accordingly, it may be because acute stroke events have become less severe and the survival rate of stroke patients is increasing.

The successful control of risk factors may have contributed to declining incidence and fatality of stroke, which may lead to the decreasing trends of stroke mortality.¹⁶⁾¹⁷⁾ In most populations, hypertension is the most attributable factor for cerebrovascular disease.¹⁸⁻²⁰⁾ In a previous study analyzing data from 1998-2011 available in the Korea National Health Nutrition Examination Survey (KNHANES),²¹⁾ the age-adjusted prevalence of hypertension decreased by 0.2 to 0.3 percent annually. The study reported that mean systolic BP level decreased by 8 mmHg in men and by 10 mmHg in women during this period which suggested that decreasing BP was largely due to lowered BP levels among patients with diagnosed hypertension.²¹⁾ The improved BP control might contribute to the remarkable decrease in stroke mortality in

Korea. In another systematic review of data from Korean or other populations, the attributable risk of hypertension for ischemic stroke was 19.9 to 30.5% in men and 17.1 to 26.6% in women.²²⁾ At ages 40 to 69, usual BP is directly related to stroke mortality in a meta-analysis of clinical trials.²³⁾ On the other hand, a few studies were unconvincing that improvement in control of hypertension resulted in a decline of mortality from stroke.²⁴⁾ However, according to a meta-analysis of clinical trials in 1992, anti-hypertensive treatment reduced fatal strokes by 33% and cardiovascular mortality by 22%.²⁵⁾²⁶⁾ The use of cholesterol-lowering medications also decreased stroke risk and mortality in observational studies and clinical trials.²⁷⁾²⁸⁾ Improved acute stroke management might also contribute to the mortality decline.⁷⁾ Between 1998 and 2002, the prevalence of hypertension decreased, whereas the prevalence of hypercholesterolemia significantly increased in both sexes.⁴⁾ Smoking rate decreased only in men, whereas the prevalence of diabetes did not change over time. Another study reported epidemiologic trends of ischemic stroke between 2002 and 2010, by analyzing data from the Korean Stroke Registry.²⁹⁾ Patient's age steadily increased, while prevalence of risk factors such as hypertension, diabetes, and smoking declined. Although cerebrovascular disease mortality rate has decreased over the last 30 years, cerebrovascular disease still remains a great burden to society and is a major cardiovascular risk factor prevalent among Koreans. To further reduce the burden of cerebrovascular disease, we need to monitor the trends of mortality from cerebrovascular disease and its subcategories, because management and prevention strategies for different stroke types vary.

The major strength of the present study is that it analyzed nationwide mortality data covering 30 years in the Korean population. But, there are also several limitations to be discussed. First, validity of cause of death can be debated. The Statistics Korea report annually the Cause of Death Statistics, and the database are primarily based on the death certificates. A previous study retrospectively compared the Cause of Death Statistics with hospital medical records, and reported the overall accuracy of causes of death as 91.9%.³⁰⁾ Second, there are still a significant number of deaths recorded without underlying causes in the Death Statistics. In 2012, 9.4% of deaths were classified as unknown, although the deaths by unknown causes are decreasing. Thus there is a possibility of underestimation of mortality from cerebrovascular disease. Third, the reported number of cerebrovascular deaths can be influenced by the health care system. Over the last decades, Korea experienced marked improvement in medical service accessibility and health care technologies. These changes might affect the reported number of cerebrovascular diseases. Lastly, there is no available nationwide data on the incidence of cerebrovascular

disease, so we cannot explore the underlying causes of changing mortality trends.

In conclusion, cerebrovascular disease mortality has significantly decreased over the last 30 years, but remains a great health burden and the prevalence of major cardiovascular risk factors are still highly prevalent in Korea. We need to continuously monitor the trends of mortality from cerebrovascular disease and its subcategories to further reduce cerebrovascular disease burdens.

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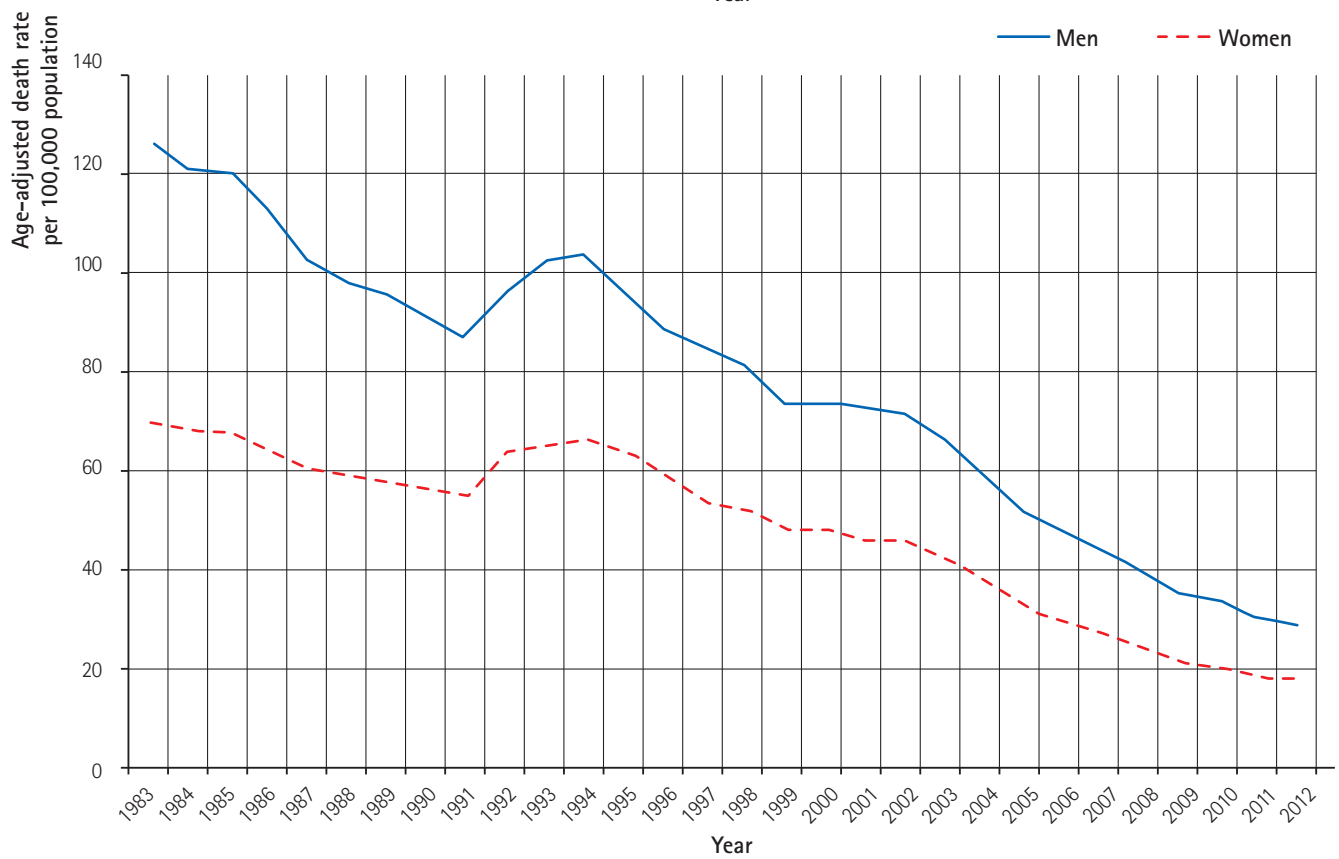
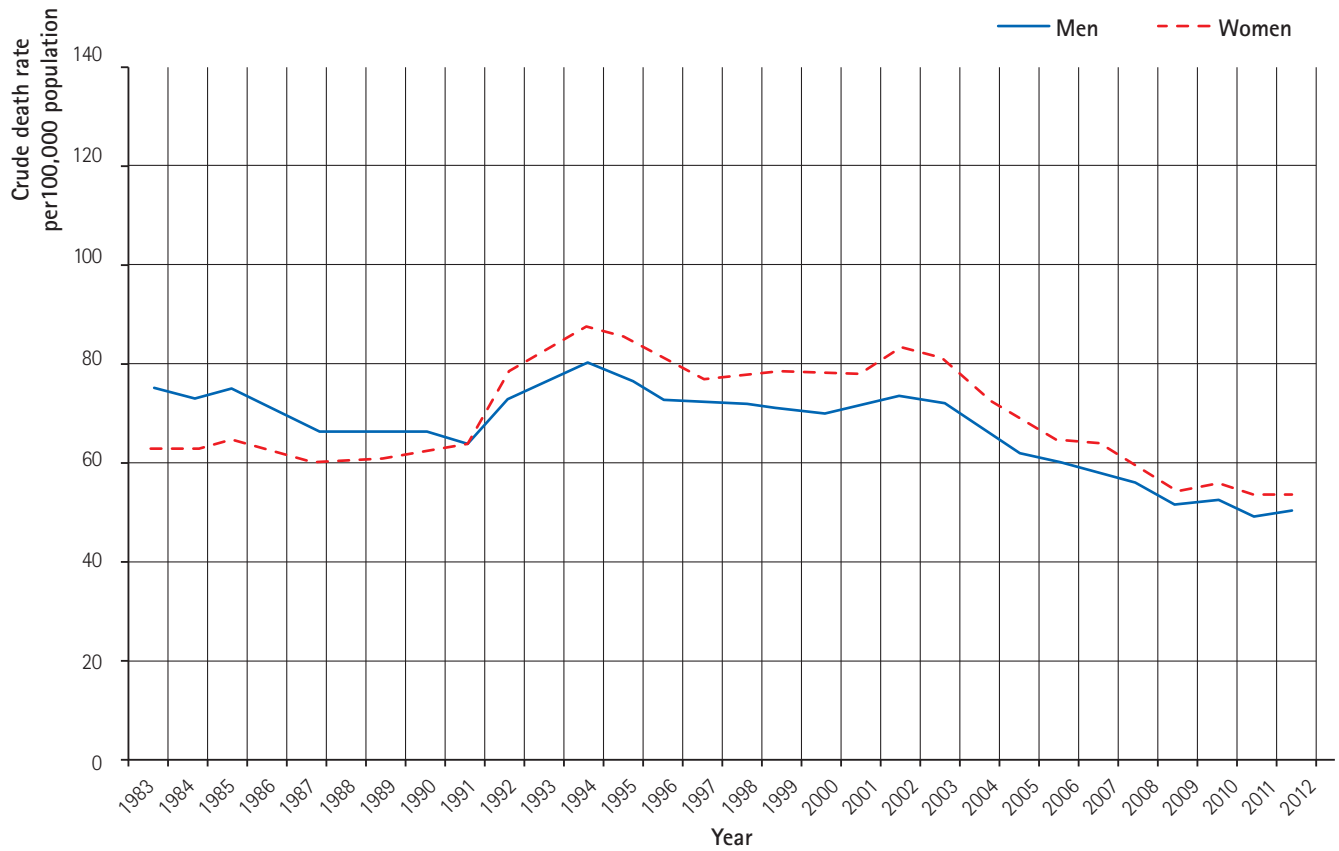
Supplementary Materials

The online-only Data Supplement is available with this article at <http://dx.doi.org/10.4070/kcj.2016.46.4.507>.

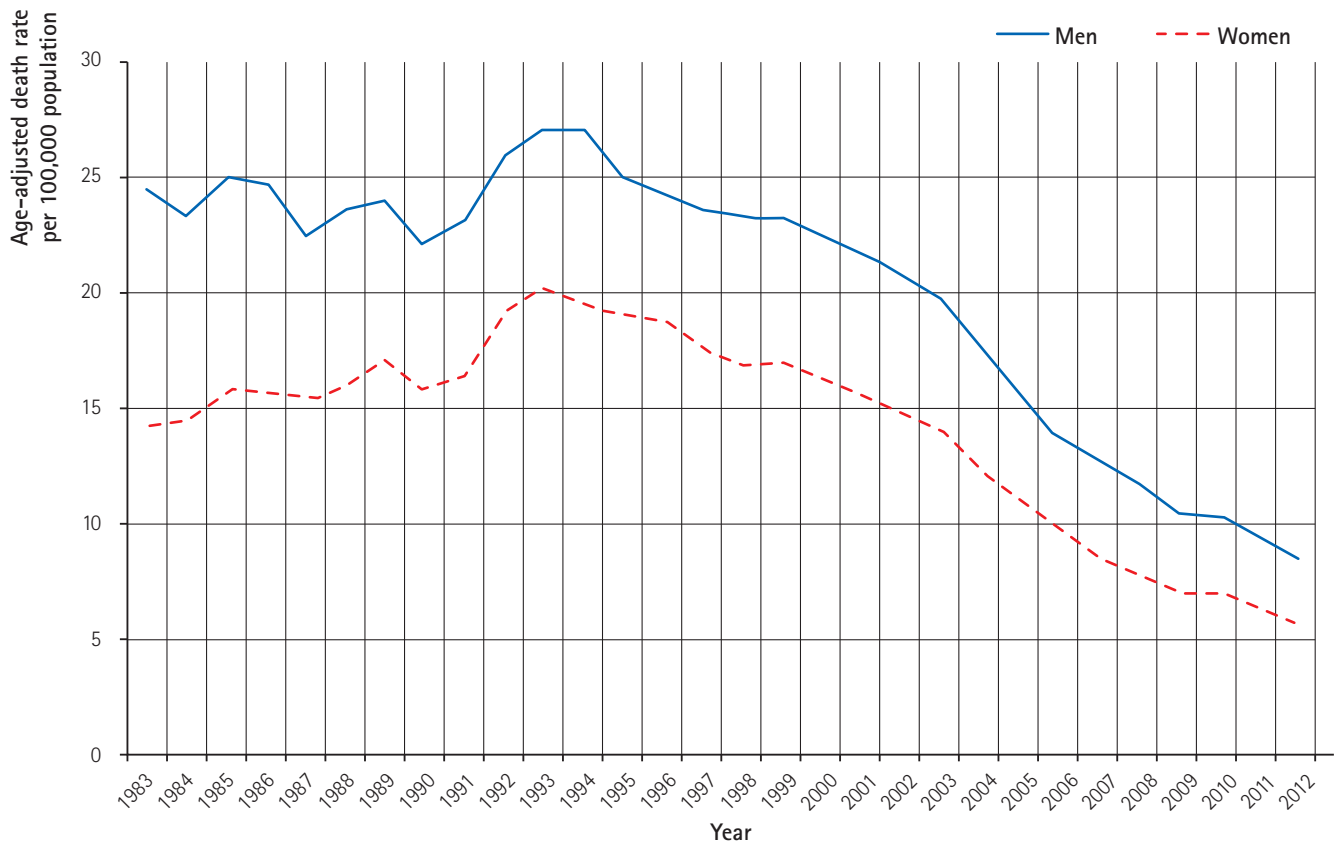
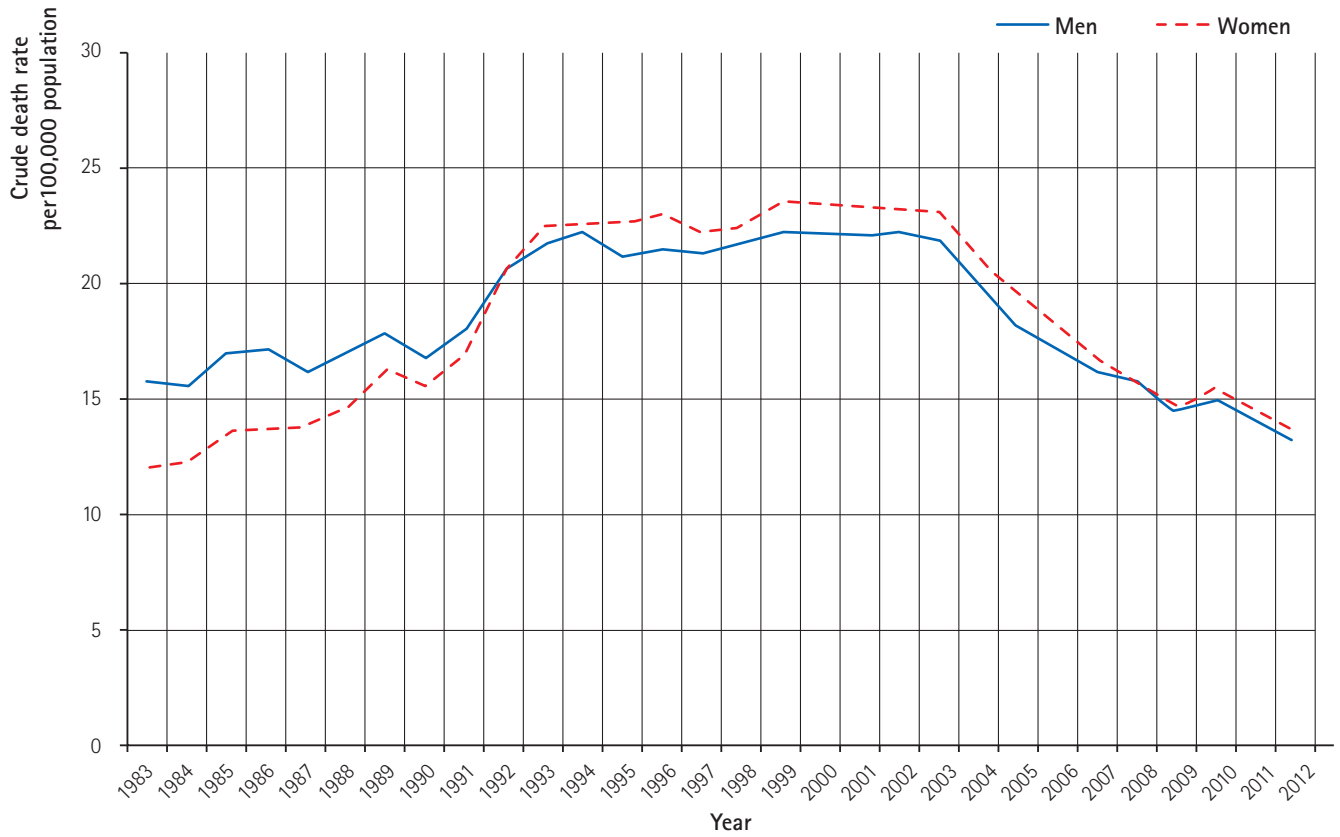
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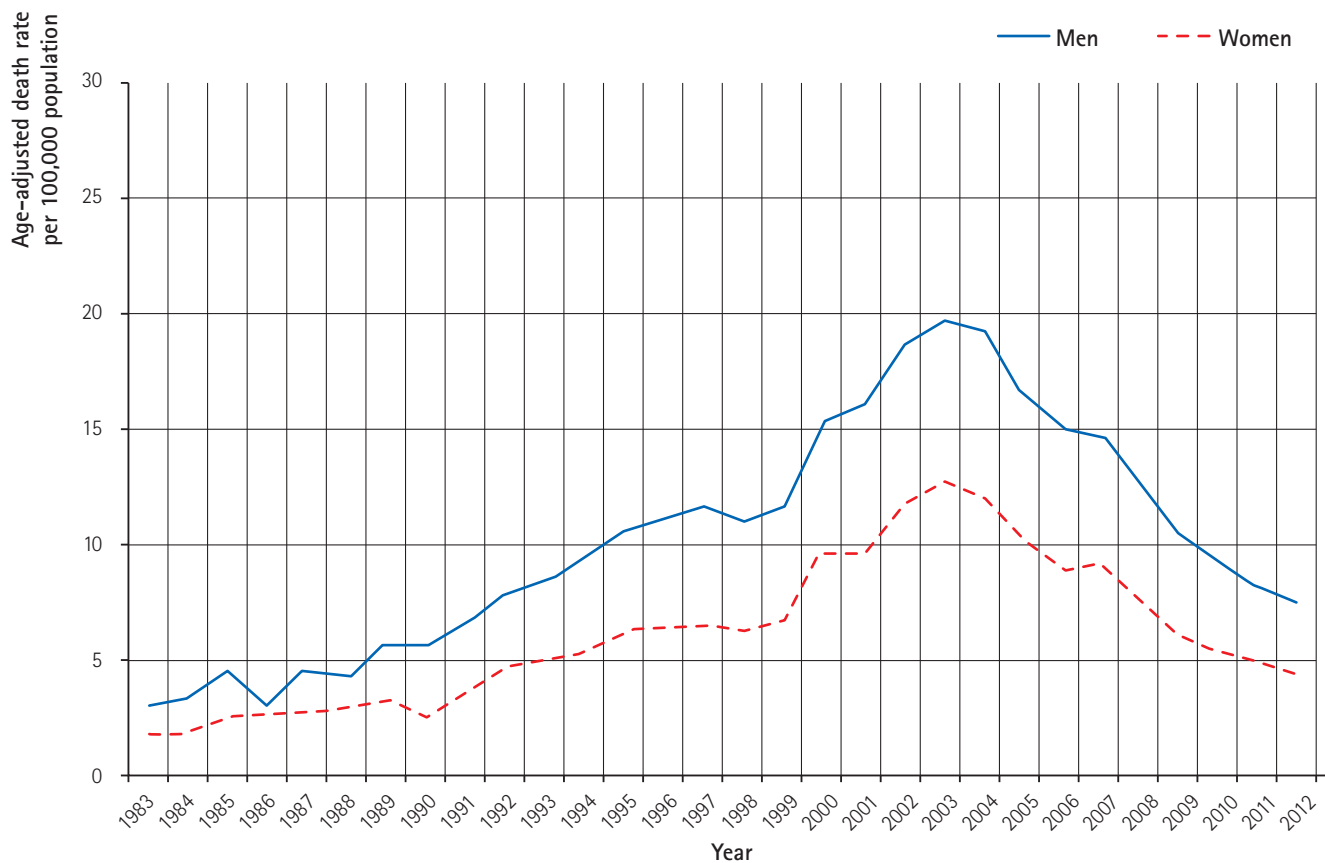
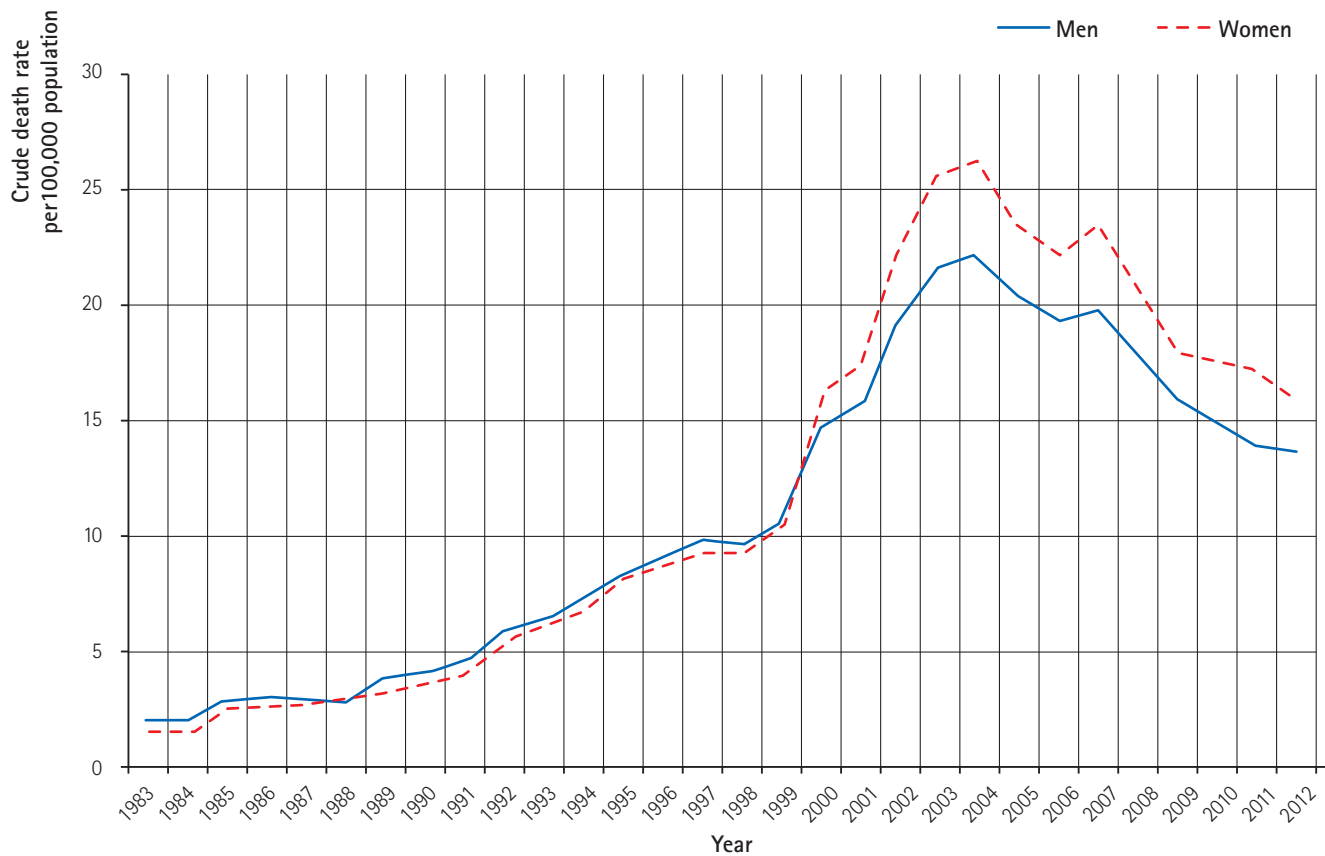
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Supplementary Fig. 1. Crude and age-adjusted mortality from cerebrovascular disease (I60-I69).



Supplementary Fig. 2. Crude and age-adjusted mortality from hemorrhagic stroke (I60-62).



Supplementary Fig. 3. Crude and age-adjusted mortality rates from cerebral infarction (I63).